

Proceedings of the American Academy of Arts and Sciences.

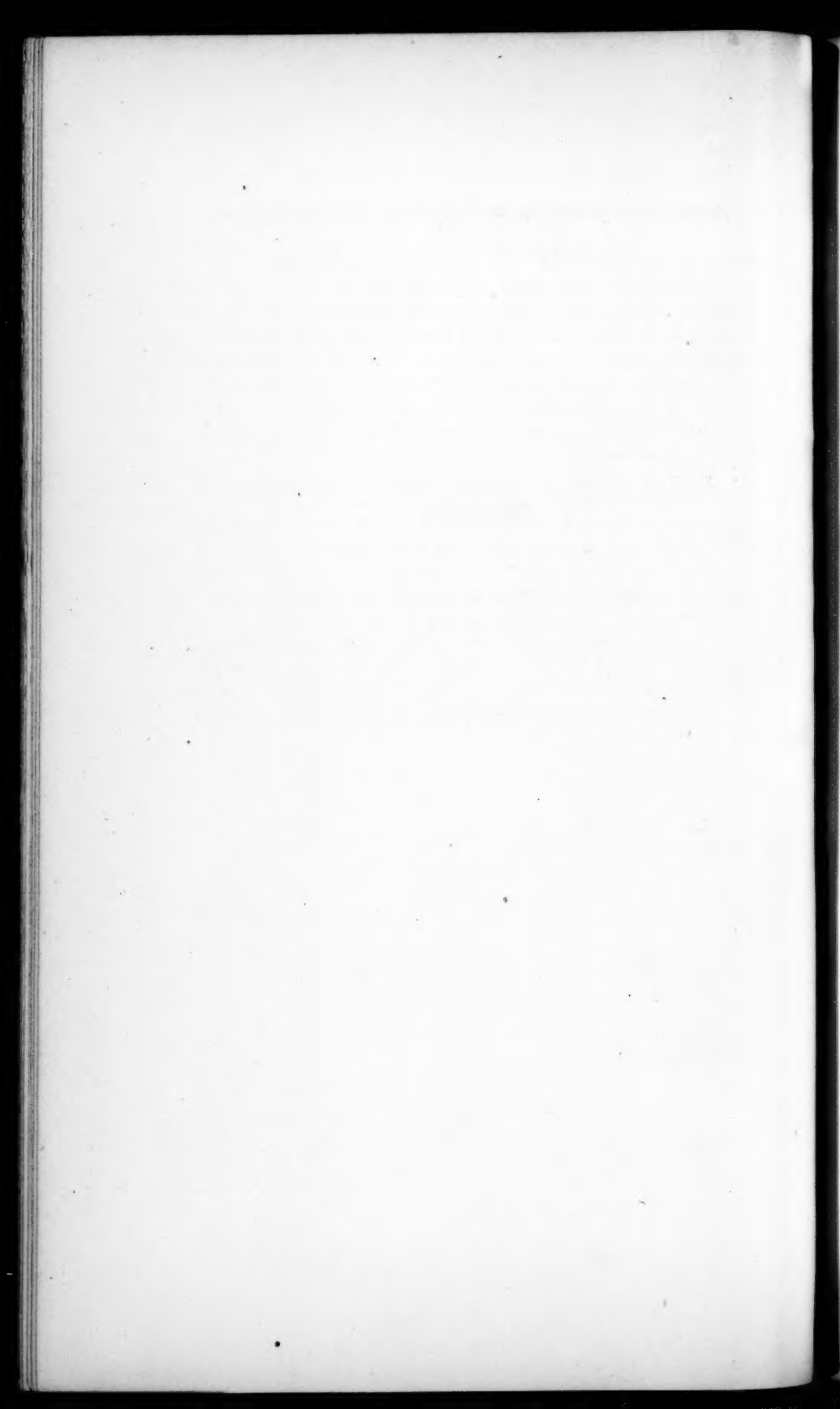
VOL. XXXVI. NO. 16. — JANUARY, 1901.

---

*THE ECLIPSE CYCLONE AND THE DIURNAL  
CYCLONES.*

RESULTS OF METEOROLOGICAL OBSERVATIONS IN THE SOLAR ECLIPSE OF  
MAY 28, 1900.

By H. HELM CLAYTON.



## THE ECLIPSE CYCLONE AND THE DIURNAL CYCLONES.

RESULTS OF METEOROLOGICAL OBSERVATIONS IN THE SOLAR ECLIPSE OF  
MAY 28, 1900.

BY H. HELM CLAYTON.

Presented November 14, 1900. Received December 12, 1900.

THE path of total solar eclipse in the United States on May 28, 1900, was visited by a number of experts and trained observers, who took meteorological observations as a part of the program on the day of the eclipse. These included Mr. A. Lawrence Rotch and Mr. S. P. Fergusson at Washington, Ga.; Mr. O. B. Cole at Centerville, Va.; Mr. G. W. Pickard at Virginia Beach, Va.; and myself at Wadesboro, N. C. These observations were sent to the Blue Hill Meteorological Observatory and given to me for discussion. Besides these I obtained records from a number of well-equipped observatories in North America. These included the Toronto Observatory, the New York Central Park Observatory, the Blue Hill Observatory, the Belen College Observatory of Havana, the McGill College Observatory of Montreal, the Meteorological Station at Cornell University, the City Engineer's Office at Providence, R. I., and observations by Mr. Eddy at Bayonne, N. J. These observations were all within the area of partial eclipse, and the data were furnished by the kindness of the directors.

The details of the discussion of the observations are published in a Bulletin of the Blue Hill Meteorological Observatory.\* The results embody certain conclusions of general interest which I am permitted to present to the Academy.

The meteorological changes due to the eclipse were separated from other changes of greater length, such as the diurnal and cyclonic, by interpolating a uniform change between the beginning and the end of the eclipse and subtracting this from the observations. For example, in Figure 1 is plotted the observations of temperature at Wadesboro, N. C.

---

\* Annals of the Astron. Observatory of Harvard College, XLIII. No. 1.

The outside vertical lines B and E show the beginning and end of partial eclipse, and the central vertical lines T show the times of total eclipse. The dotted straight line connects the observed temperature at the begin-

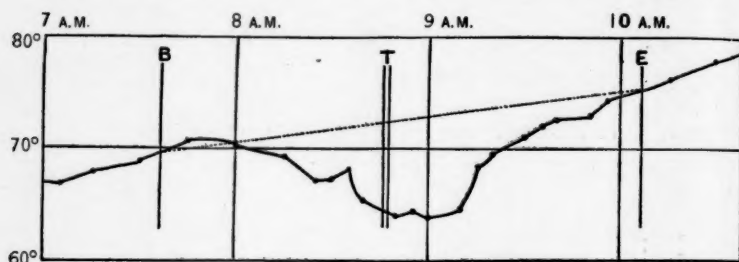


FIGURE 1.

ning and end of the eclipse, and represents the interpolated uniform change. The observed temperatures are shown by the unbroken curved line, and the departures of these from the values represented by the dotted line is assumed to be the depression of temperature arising from the eclipse. The pressure, humidity, and vapor tension were treated in the same manner.

In order to obtain the eclipse wind in velocity and direction, the observations were treated in the following manner.

In the accompanying diagram, Figure 2, let A B represent the direction and velocity of the wind prevailing independent of the eclipse, and

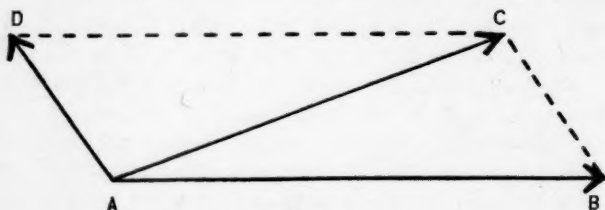


FIGURE 2.

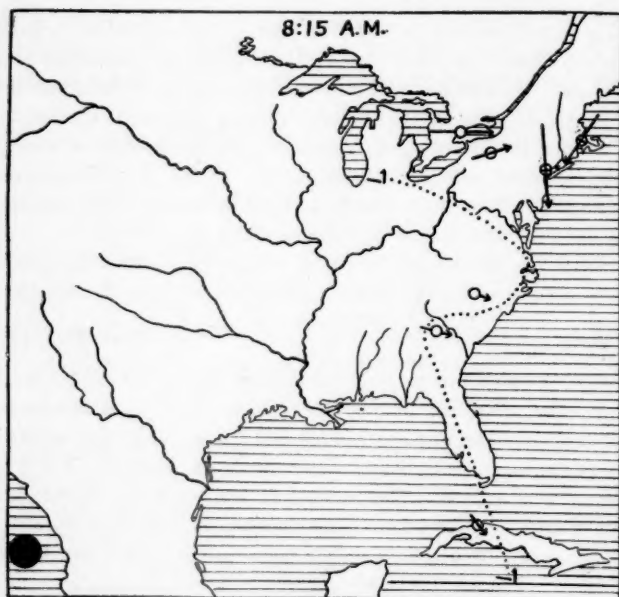
A C the wind observed at any moment during the eclipse; then completing the parallelogram of forces, A D will represent the eclipse wind in direction and velocity. The prevailing wind was derived from the mean of the winds immediately preceding and following the penumbra, or, what was found to be practically the same thing, from the mean wind direction during the passage of the penumbra, since the eclipse wind was

from opposite directions during this time. The penumbra is used to indicate the area of partial eclipse, and the umbra to indicate the area of total eclipse. The mean wind and the eclipse wind were at first determined graphically for all the stations; then as the results seemed to be of importance, they were rigidly computed for all the stations where the observations were sufficiently accurate to warrant it. These results, when plotted, indicate very clearly an outflow of wind from around the umbra, and an inflow around the borders of the penumbra.

But there are certain irregularities due to the normal irregularities of the wind. In order to diminish the effect of these, I smoothed the observations by the formula  $\frac{a + 2b + c}{4}$ . These winds were plotted

at their proper places on maps of the United States for 8.15 A.M., 75th meridian time, when the umbra was about to enter the American continent from the Pacific, and also plotted for 9 A.M., when the umbra had passed off the coast of the United States on to the Atlantic. These maps are shown in Figure 3. The position of the umbra is shown on each map by a dark circular area. The depressions of temperature by the eclipse are shown by numerals on the maps, and isotherms are shown by dotted lines. The weather conditions are indicated by symbols, and the direction and velocity of the eclipse wind are indicated by the direction and length of the arrows. The winds were practically reversed in direction as the umbra moved from one side of the continent to the other, but both charts show a distinct anticyclonic circulation and an outflow of air extending from the umbra, or central area of the eclipse, to a distance of about fifteen hundred or two thousand miles. In the 8.15 A.M. chart the outer limit of the outflow appears to be in New York, beyond which there is an inflow. In this chart the stations of observations are so far in advance of the central area of the eclipse that no appreciable depression of temperature is shown; but in the 9 A.M. chart, which coincides with the greatest depression of temperature at Wadesboro, Washington, and Virginia Beach, there is a central area shown by the isotherms where the depression of temperature exceeds 8° F. This area of greatest cold lags behind the umbra about five hundred miles.

The charts in Figure 3 show only a portion of the eclipse area, or penumbra, which was about five thousand miles in diameter. Hence the charts do not give an idea of the winds on the outer area of the penumbra, or the successive changes which occurred at any one station as the eclipse passed over it. A view of these changes is obtained by plotting the winds, temperature, etc., at given stations when they were successively



○ CLEAR; ⊗ FAIR; ⊗ CLOUDY.

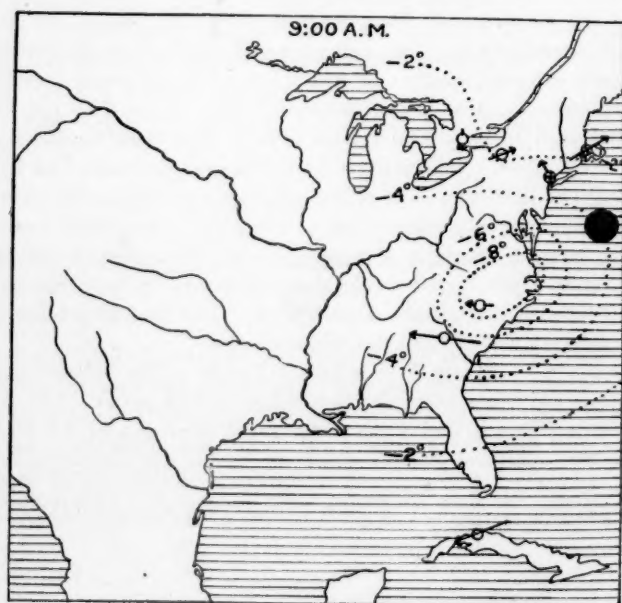


FIGURE 3.

in different portions of the eclipse area. The eclipse shadow travelled with a velocity somewhat greater than two thousand miles an hour. By placing the stations at their proper distances from the path of the umbra and plotting the successive fifteen minute observations at intervals of about five hundred miles, a synoptic chart is obtained showing the conditions observed at any given station or group of stations when they were in different portions of the eclipse area. In this way Figure 4 was constructed. In this diagram the direction and width of the path of the umbra is

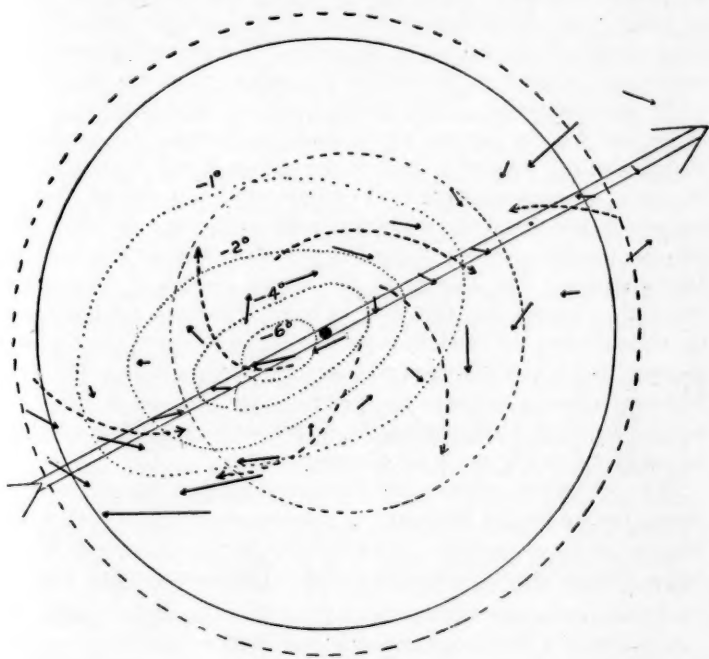


FIGURE 4.

shown by parallel lines forming a long arrow. The central shaded area shows the umbra, and the outer unbroken circle shows the outer limit of the penumbra. The data north of the path of the umbra are derived from the mean of the observations at Ithaca, Toronto, and Blue Hill; the data along the path are derived from the mean of observations at Washington, Ga., and Wadesboro, N. C.; the data south of the path are from Havana.

Figure 4 indicates distinctly an anticyclonic circulation of the wind around the centre of the eclipse extending out to a distance of about fifteen hundred miles from the umbra. Outside this area there is an equally distinct cyclonic circulation about one thousand miles in width extending out to and beyond the edge of the penumbra. Beyond this there are indications of another ring of outflowing winds. The inner circle of broken lines in the diagram represents a probable ring of low-air pressure. The outer circle of broken lines surrounding the penumbra represents a probable ring of high pressure. The isotherms are shown by dotted lines. They show an elliptical area of cold air central about five hundred miles in the rear of the umbra. The greatest depression of temperature is north of the track of the umbra. This was chiefly due to the continental effect. The difference may also have been due in part to the fact that the sky was partly cloudy at Havana. On comparing stations similarly situated as regards the eclipse, it was found that the depression of temperature due to the eclipse was less at stations where it was cloudy, and that it also diminished with height above the sea. This indicates that the cooling is chiefly in a thin stratum of air very near the earth's surface. The analogy to the diurnal change of temperature would also indicate that this must be true. The shape and position of the areas showing the humidity departures are so similar to those of temperature that it is not deemed necessary to reproduce them. The chief difference is that in one case the departures are plus and in the other minus. In other words, during the eclipse there is a rise of absolute and relative humidity and a fall of temperature.

The observations indicate very clearly a lowering of the air pressure during the eclipse, the minimum of pressure occurring soon after the minimum of air temperature. This is shown by records made at Washington, Ga., at Toronto, and at Blue Hill. The accompanying diagram

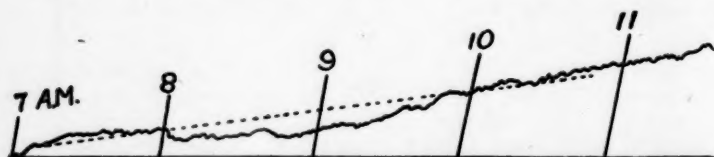


FIGURE 5.

shows a record made by an "aerograph," or air barometer, at Toronto. This barograph, devised by F. Napier Denison, has its air-chamber buried eight feet below the surface of the ground to protect it from



external changes of temperature. The curve is traced from the record, and is given on the same scale without correction in any way. The eclipse began at Toronto about 7.47 A.M. and ended about 10.18 A.M. A straight dotted line is drawn through the curve connecting the pressure recorded at the beginning and end of the eclipse. It is seen that the pressure was generally below the dotted line throughout the eclipse, but there was an upward swell between 8 and 9 A.M., shortly preceding the middle of the eclipse. Immediately preceding and following the beginning and end of the eclipse the curve rises above the dotted line, indicating a ring of high pressure surrounding the umbra, and thus agreeing perfectly with the distribution of pressure demanded by the wind circulation. I find that when the changes of pressure observed during previous eclipses are separated from the normal diurnal changes, they show changes very similar to those given by the curve for Toronto, except that the rise in pressure near the middle of the eclipse is greater for stations in the path of total eclipse. This central rise of pressure is due to the increased density of the air from cold, and on it depends the outflow of air surrounding the umbra. Hence in normal eclipses there is a central area of relatively high pressure; surrounding this is a ring of minimum pressure, and beyond this, outside the edge of the penumbra, is a ring of maximum pressure.

The low temperature, the circulation of the winds, and the form of the pressure curve accompanying the eclipse of May 28, 1900, all proclaim the development by the eclipse of a cold-air cyclone, the theory of which has been so well worked out by Ferrel that no better description of it could be given than in his own words. Ferrel maintains from theoretical considerations that cyclones necessarily have an inner area of low pressure, surrounded by a ring of high pressure, which Professor Davis has named a *pericyclone*. Ferrel further maintains that a cyclone may have its origin either in a high temperature increasing toward a central area, or in a low temperature decreasing toward a central area. The one he calls a cyclone with a warm centre, the other a cyclone with a cold centre. Of cyclones with a cold centre he says:—

“If for any reason the central part of any given portion of the atmosphere of a somewhat circular form is maintained in any way at a lower temperature than the surrounding parts, and the temperature gradient on all sides is somewhat symmetrical, we have approximately the conditions which give rise to a cyclone. In this case it is readily seen that there must be a vertical circulation, as in the ordinary cyclone, but that it is reversed, out from the centre below, and in toward the centre above,

with a gradual settling down of the air in the interior to supply the outward current beneath. This vertical circulation, as in the case of the ordinary cyclone, gives rise to a cyclonic motion in the interior and an anticyclonic in the exterior part of the air under consideration, but in this case the gyratory velocity is greatest above and is less at lower altitudes, diminishing down to the earth's surface, where it is least. In the anticyclonic part the reverse takes place, the gyratory velocity being least above and greatest down near the earth's surface. The distance from the centre at which the gyratory velocity vanishes and changes sign, is greatest above and gradually becomes less, with decrease of altitude down to the earth's surface, where it is nearest the centre. . . . The conditions of a cyclone with a cold centre which are the most nearly perfect are those furnished by each hemisphere of the globe, as divided by the equator, in which the pole is the cold centre, and the temperature gradient from the pole toward the equator is somewhat symmetrical in all directions from the centre. . . . The easterly motions in the higher latitudes and the westerly ones in the lower latitudes, in the one case, correspond to the cyclonic in the interior and the anticyclonic in the exterior part, and the belt of high pressure near the tropics to that of high pressure in the case of any cyclone with a cold centre. . . . The centre of a cyclone with a cold centre may or may not have a minimum pressure, according to circumstances. A certain amount of temperature gradient, and of pressure gradient which is independent of the gyratory motion, as explained in the case of the general circulation of the atmosphere, is necessary to overcome the friction in the lower strata and to keep up the vertical circulation, upon which the cyclone depends; and the pressure gradient, which depends upon the temperature gradient and is independent of the gyrations, may be such that the increase of pressure in the central part due to this cause may be greater than the decrease of pressure arising from the cyclonic gyrations, especially where surface friction is great." \*

The eclipse cyclone is of especial interest from a theoretical point of view, because its origin, clearly connected with the fall of air temperature attending the eclipse, is freed from all questions of condensation of vapor or of the dynamic effects due to the meeting of air currents whose possible influence complicates the question as to the origin of the ordinary cyclone. The eclipse may be compared to an experiment by Nature in which all the causes that complicate the origin of the ordinary

---

\* A Popular Treatise on the Winds, pp. 337-339.

cyclone are eliminated except that of a direct and rapid change of temperature. The results derived from the observations by eliminating the influence of other known phenomena give quantitatively the effects of a given fall of temperature near the earth's surface in a given time. They show that a fall of temperature is capable of developing a cold-air cyclone in an astonishingly short time, with all the peculiar circulation of winds and distribution of pressure which constitute such a cyclone. They show, furthermore, that a fall of temperature of the air does not act primarily to cause an anticyclone but a cyclone, and the anticyclone is a secondary phenomenon, or rather a part of the cyclone.

The eclipse cyclone shows no apparent lag or dynamic effect due to the inertia of the air. To keep pace with the eclipse shadow moving about two thousand miles an hour the eclipse cyclone must continuously have formed within the shadow and must have dissipated in the rear almost instantly. In this way its motion may be considered to have a certain analogy to wave motion. Any given particle of air moving with the velocity of the eclipse winds could not have moved more than five miles as a maximum during the passage of the eclipse. Hence all the changes of pressure must have been derived from the deflective influence of the earth's rotation acting on air moving this distance.

In brief, the meteorological effects of the eclipse are important —

(1) Because they confirm so fully Ferrel's theory of the cold-air cyclone;

(2) Because they show the wonderful rapidity with which cyclonic phenomena can develop and dissipate in the atmosphere; and

(3) Because they show that cyclones do not necessarily drift with the atmosphere, but move with their originating cause, which in the eclipse had a progressive velocity of about two thousand miles an hour.

#### THE DIURNAL CYCLONES.

The discovery that the brief fall of temperature attending a solar eclipse produces a well-developed cyclone which accompanies the eclipse shadow at the rate of about two thousand miles an hour, suggests that the fall of temperature due to the occurrence of night must also produce or tend to produce a cold-air cyclone. Since the heat of day produces or tends to produce a warm-air cyclone, there must tend to occur each day two minima of pressure, one near the coldest part of the day, and another near the warmest part of the day, with areas of high pressure between them due to the overlapping of the pericyclones surrounding the

cold-air and the warm-air cyclones respectively. These causes must produce entirely or in part the well-known double diurnal period in air pressure. At any rate, in view of the fact that an eclipse causes a cyclone over half a hemisphere, it will be necessary before rejecting such a theory to show that the fall of temperature at night does not produce a cyclone, or that this cyclone and the corresponding warm-air cyclone of the day do not appreciably influence the barometer.

The points in favor of the theory that the double diurnal period in pressure is due to two diurnal cyclones, one developed by the cold of night and the other by the heat of day, may be stated in brief as follows. The theory is based on well-known physical laws. The possibility of a cold-air cyclone under conditions similar to the diurnal cyclone is confirmed by the eclipse cyclone. The theory explains the annual oscillation of the time of maxima and minima of pressure in the diurnal period; and explains the occurrence of a third maximum in high northern latitudes in winter. The theory also explains why the warm-air cyclone is well developed over continents, and on clear days, and causes a marked fall in the barometer during the afternoon, while the morning minimum of pressure over continents does not attain an excessive development as compared with that over oceans where there is slight retardation of the air movements on which the fall of the barometer in the cold-air cyclone depends.

The diurnal cyclones move from east to west, contrary to the motion of ordinary cyclones in temperate latitudes. Their velocity of motion is about one thousand miles an hour at the equator, and diminishes toward the poles. The two charts in Figure 6 indicate the circulation of the surface winds and upper currents in the diurnal cyclones. In these charts the ordinates represent the hours of the day, and the abscissas represent distances from the equator. The data for the surface winds are derived from observations at Blue Hill, lat.  $42^{\circ} 13' N.$ , long.  $71^{\circ} 7' W.$ , and Cordoba, Argentina, lat.  $31^{\circ} 25' S.$ , long.  $64^{\circ} 12' W.$ \* The directions of the arrows represent in the usual way wind directions, and the position of the arrow shows the time of maximum frequency of each wind. Thus the greatest diurnal frequency of southerly winds occurs at Cordoba at 7 A.M., and at Blue Hill between 7 and 8 P.M. There is also a second maximum frequency of southerly winds at Blue Hill about 10 A.M. The wind arrows at Cordoba and Blue Hill are, in general,

---

\* *Annals of the Astron. Observatory of Harvard College*, XXX. Pt. iv., 415 and 419.

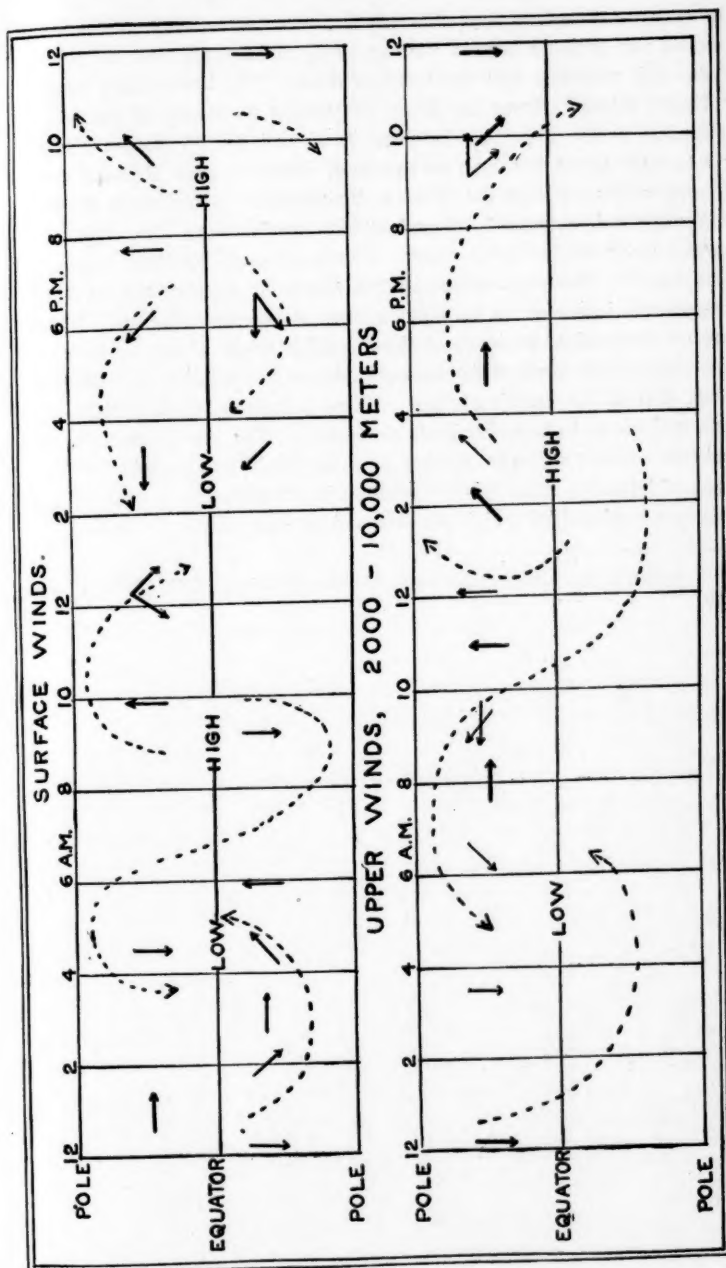


FIGURE 6.

in opposite directions, and distinctly indicate a circulation of the wind around two cyclonic centres passing along the equator, and an outflow from high pressures half-way between them. The lower chart, headed "Upper Winds," shows the hours of greatest frequency of each wind direction in the upper air between 2,500 and 10,000 meters. These times were determined by observations of clouds at Blue Hill, and from hourly wind records on the Säntis in Switzerland. Cloud strata at three different levels between 3,000 and 10,000 meters above Blue Hill each gave a result similar to the other. This is indicated by heavy arrows in the chart.\* The observations on the Säntis at an elevation of 2,500 meters are indicated by the light arrows in the same diagram. There are no observations available at these heights south of the equator, but the observations north of the equator indicate a circulation very different from that at the earth's surface. There is apparent at this height only one cyclonic and one anticyclonic circulation. The low pressure in the cold-air cyclone of night persists at these levels, and probably with increased intensity, while the low pressure in the warm-air cyclone of day has been replaced by a high pressure and an anticyclonic circulation.

---

\* *Annals of the Astron. Observatory of Harvard College*, XXX. Pt. iv., 415 and 419.

